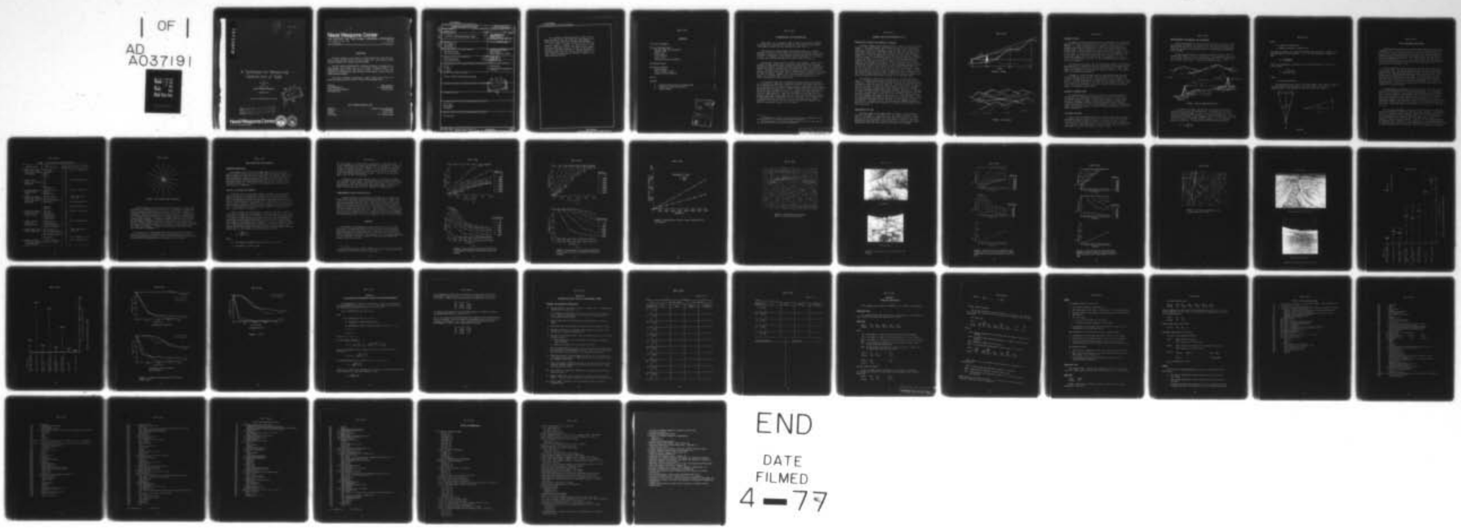
AD-A037 191 NAVAL WEAPONS CENTER CHINA LAKE CALIF F/G 8/6
A TECHNIQUE FOR MEASURING OPTICAL LINE OF SIGHT.(U)
JAN 77 C J BURGE, J H LIND
UNCLASSIFIED NWC-TP-5916 NL

1 OF 1
AD
A037191



END
DATE
FILMED
4-77

12

NWC TP 5916

A Technique for Measuring Optical Line of Sight

by
Carol J. Burge
and
Judith H. Lind
Systems Development Department

JANUARY 1977

Naval Weapons Center
CHINA LAKE, CALIFORNIA 93555

Naval Weapons Center

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

R. G. Freeman, III, RAdm., USN .... Commander

G. L. Hollingsworth .... Technical Director

FOREWORD

This report documents a study conducted at the Naval Weapons Center, China Lake, Calif. between January and July 1976. The work was conducted under a target acquisition program supported by MIPR RA 46-75, AMCMS Code 675702.12.86300.

The Joint Technical Coordinating Group for Munitions Effectiveness is sponsoring work on surface-to-surface target acquisition under its Joint Munitions Effectiveness Manual for the Surface-to-Surface Division. Current tasks include the summary of field test data from target acquisition tests, experimentation on target camouflage, and the collection of data on terrain and foliage masking (intervisibility).

This report is a handbook for determining line of sight in different types of terrain. It was reviewed for technical accuracy by Ronald A. Erickson of the Naval Weapons Center.

Released by
M. M. ROGERS, *Head*
Systems Development Department
16 November 1976

Under authority of
G. L. HOLLINGSWORTH
Technical Director

NWC Technical Publication 5916

Published by ....Technical Information Department
Manuscript 2362/MS BO430
Collation ....Cover, 23 leaves
First printing ....175 unnumbered copies

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NWC-TP-5916	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (*and Subtitle*) A Technique for Measuring Optical Line of Sight		5. TYPE OF REPORT & PERIOD COVERED ~~Target acquisition study~~ Technical publication January–July 1976
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Carol J. Burge, Judith H. Lind		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Weapons Center, China Lake, Calif. 93555		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS MIPR RA 46-75, AMCMS Code 673702.12.86300
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Weapons Center, China Lake, Calif. 93555		12. REPORT DATE January 1977
		13. NUMBER OF PAGES 44
14. MONITORING AGENCY NAME & ADDRESS(*if different from Controlling Office*) 44p.		15. SECURITY CLASS. (*of this report*) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Line of sight
Terrain masking
Intervisibility

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

See back of form.

(U) *A Technique for Measuring Optical Line of Sight*, by Carol J. Burge and Judith H. Lind. China Lake, Calif., Naval Weapons Center, January 1977. 44 pp. (NWC TP 5916, publication UNCLASSIFIED).

(U) This report, a companion to NWC TP 5908, *Line-of-Sight Handbook*, explains the techniques and equipment used to obtain the operational information contained in that report. Surveying equipment was used to make precise measurements of ranges to and elevations of objects which mask a target site from view. The eight classifications of terrain studied are described, along with procedures for selection of sites where measurements were made.

CONTENTS

INTRODUCTION AND BACKGROUND

This report is a companion to NWC TP 5908, *Line-of-Sight Handbook*. Its purpose is to explain how the data were collected and the computations made to produce the data presented in that report.

The objective of this masking measurement program is to present probability of line of sight (LOS) as a function of terrain, range, and altitude. Preparation of the handbook included carrying out a literature search[1,2] to determine if the required data existed and, if it did not, if there was a proven technique that could be used to obtain it.

Map studies, field studies, and models were examined. Models were rejected for use because their correlation with reality was not known. Information obtained from maps has many advantages, but also limitations--mainly that there is no good way to determine the effects of vegetation on LOS. There were some field data in existence, but information was all gathered for particular sites, with no attempt made to generalize according to types of terrain. However, the literature search did result in discovery of a technique that could be used, with some modification, to obtain desired data on LOS in the field.

As a result of the lack of detailed and generalizable information, it was decided to undertake a measurement program that would describe the LOS characteristics of various types of terrain. The method to be used was an extension of that used to measure masking around each of the targets during the JTF-2 flight trials in 1965.[1] Those researchers measured the elevation angle and range to objects surrounding the target which mask it from view (mask objects). From this information, the probability of having a clear LOS to the target from any range and altitude was computed. The NWC measurement program described in this report used the same type of measurements, but from several sites in the same kind of terrain. Probability of clear LOS for each terrain type was then computed. The method is explained in detail in this report.

---

[1] Naval Weapons Center. *A Review of Ground Target Masking Effects*, by Carol J. Burge and Robert Stohler. China Lake, Calif., NWC, June 1974. (NWC TP 5668, publication UNCLASSIFIED.)

[2] Naval Weapons Center. *A Review of Surface-to-Surface Masking Studies*, by Carol J. Burge. China Lake, Calif., NWC, June 1975. (NWC TP 5773, publication UNCLASSIFIED.)

THEORY AND DATA-GATHERING PLAN

MASK ANGLE, RANGE, AND CRITICAL ALTITUDE

Consider a single radial extending from a target or site at S, as in Figure 1. The angle between the horizontal plane (H) and a line with origin at S which is high enough to clear the tree is m_1. That is the mask angle of the tree. The angle needed to clear the first hill is m_2. An observer standing at ground level between S and the tree can see a target at S. If he is between the tree and the first hill at a range R from the target, S, the observer must be at least as high as the value of R tan m_1 in order to see S. Between the first and second hills, an observer must have an altitude of at least R tan m_2 in order to see S. Similarly, an altitude of at least R tan m_3 is needed to see S from a range which is beyond the second hill. These altitudes necessary to have a clear LOS to the site are called critical altitudes (CA_1, CA_2, CA_3, and CA_4 on Figure 2). They are a function of the terrain and of range. For any range, R, critical altitude is equal to R tan m, where m is the mask angle in effect at that range. Whether LOS exists to the site from any range-altitude combination can be determined simply by comparing the given altitude with the critical altitude at the required range.

Now consider a circle with circumference at a given range from a site, S, cutting through the many radials extending out from that site (Figure 2). There is a critical altitude value, CA, at each range-radial intersection (four are shown in Figure 2). The mean of these is the mean critical altitude for that range, with respect to that site. Assuming that the critical altitudes are normally distributed, about half the critical altitudes would be higher than the mean. Therefore, if one were to travel the range circle's circumference at the mean critical altitude, one would expect to have a clear LOS to the site about 50% of the time. Critical altitudes with higher probabilities of a clear LOS may be found by adding standard deviations to the mean, because the mean plus or minus two standard deviations contains about 95% of the values in a normal distribution. The mean critical altitude plus two standard deviations should be an altitude with a probability of about 0.975 of having a clear LOS to the site.

PROBABILITY OF LOS

Referring again to the range circle in Figure 2, the probability of having a clear LOS to S from the circle, at a given altitude, is the ratio of the number of radials for which that given altitude is higher than the critical altitude to the total number of radials. Thus, once measurements have been made of mask angles and of range to mask objects, probability of LOS for any range and altitude can be computed.

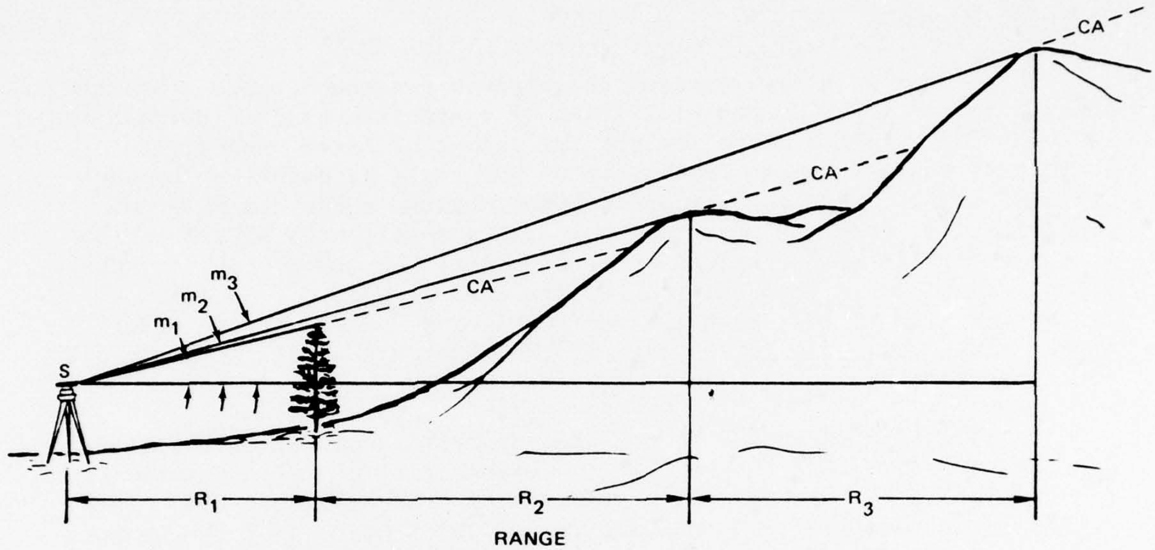


FIGURE 1. A Radial.

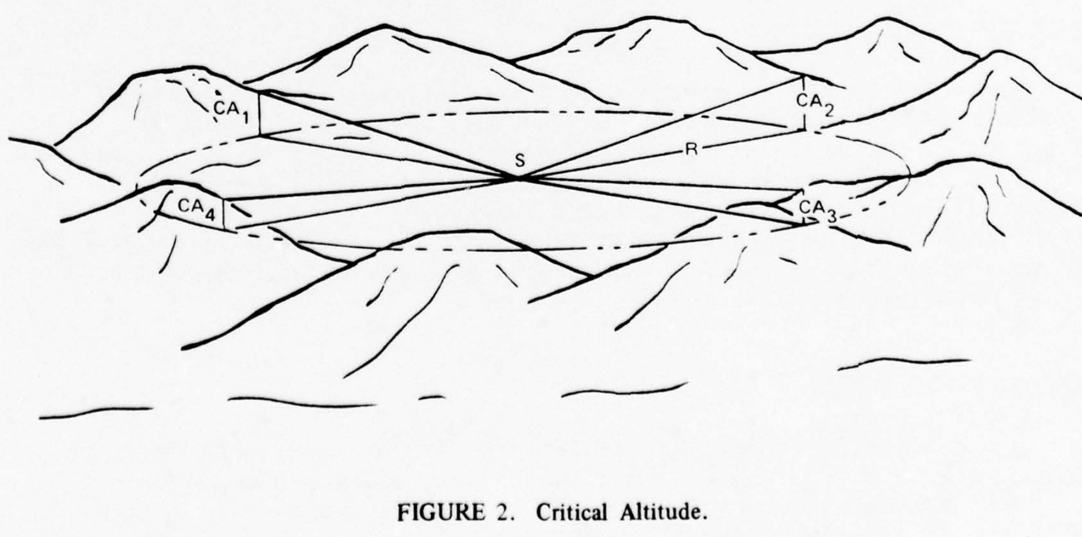


FIGURE 2. Critical Altitude.

NUMBER OF SITES

The number of sites required to obtain a reasonably good statistical description of the LOS characteristics of a specific kind of terrain was unknown. To obtain a guideline for the number of sites needed, the assumption was made that probability of LOS could be described by the binomial model. This assumption was made because there are only two possibilities, from any observation point in space, with regard to LOS to the site: it either exists or it does not. If the probability that it does exist is p, then the probability that it does not is 1-p. It is further assumed that each test of LOS is independent of the other tests. This obviously is not true if the observation points tested are too close together.

Calculations were made to get the approximate number of LOS measurements needed for a 95% chance that the probability of LOS estimated from the data would lie within ± 0.1 of the actual probability of LOS. This number was determined to be between 75 and 100. Details of the computations are included in Appendix A.

Although it could be argued that each measurement along a radial could be counted toward the 75 to 100 required, it was decided to try to work with between 75 and 100 separate radials in each category of terrain. To keep measurements as independent as possible, only 16 radials per site would be measured, at intervals of approximately 22.5 deg. Five or six sites were needed for each terrain type, to obtain the desired number of independent measurements.

TERRAIN CLASSIFICATION

To determine LOS as a function of terrain, the various kinds of terrain had to be separated into categories. Sites were classified according to two properties: contour and vegetation. Contour ranged from flat farmland to sharply rolling hills; vegetation ranged from scattered low bushes to dense forests surrounding a small clearing. Final classification of a site was determined on the basis of how terrain looked on topographic maps, in aerial and ground photographs, and from direct observation.

LOCATION OF SITES

Areas of quite homogeneous terrain in each category were outlined on topographic maps and, within the areas, sites from which measurements would be made were tentatively marked. An effort was made to locate each site in an area "typical" of the terrain type, with no uncharacteristic features. Sites were selected in an "average" position within the area--that is, not on the highest or lowest ground.

MEASUREMENT TECHNIQUES AND EQUIPMENT

Some time was spent investigating the possibility of using a laser range finder for making the required range and elevation measurements. The idea was reluctantly abandoned because of safety restrictions that would have severely limited the choices of terrain where measurements could be made.

It was decided to employ a standard surveying technique using two theodolites, which we will call Th_1 and Th_2. The theodolites were set up, as shown in Figure 3, both aimed at the same point, P. The elevation of the point, with respect to Th_1, was measured, using only Th_1.

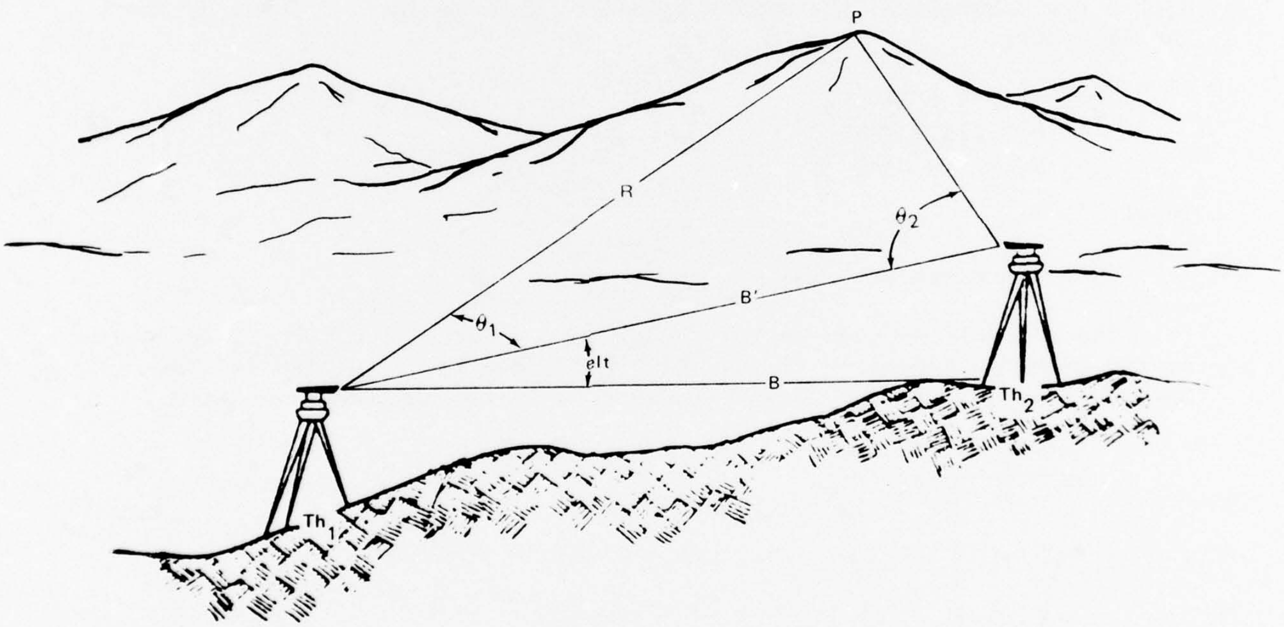


FIGURE 3. Range and Mask Angle Measurement.

To determine the range, the distance B´ between Th_1 and Th_2 is measured with the aid of a subtense bar. A subtense bar is a bar of accurately measured length, X, with a level and telescope on it for sighting on the theodolite being used to make the measurement. The bar was mounted on the Th_2 tripod, perpendicular to the line between Th_1 and Th_2, as in Figure 4a, and the angular subtense, α, of the bar was measured, using Th_1. B´ was calculated from the equation below.

$$B' = \frac{X}{2 \tan \alpha/2}$$

where

X = length of subtense bar

α = angular subtense of subtense bar.

The elevation angle, elt, between theodolites was measured to correct for any difference in their heights. $B = B' \cos elt$, as shown in Figure 4b. Then

$$B = \frac{X \cos elt}{2 \tan \alpha/2}.$$

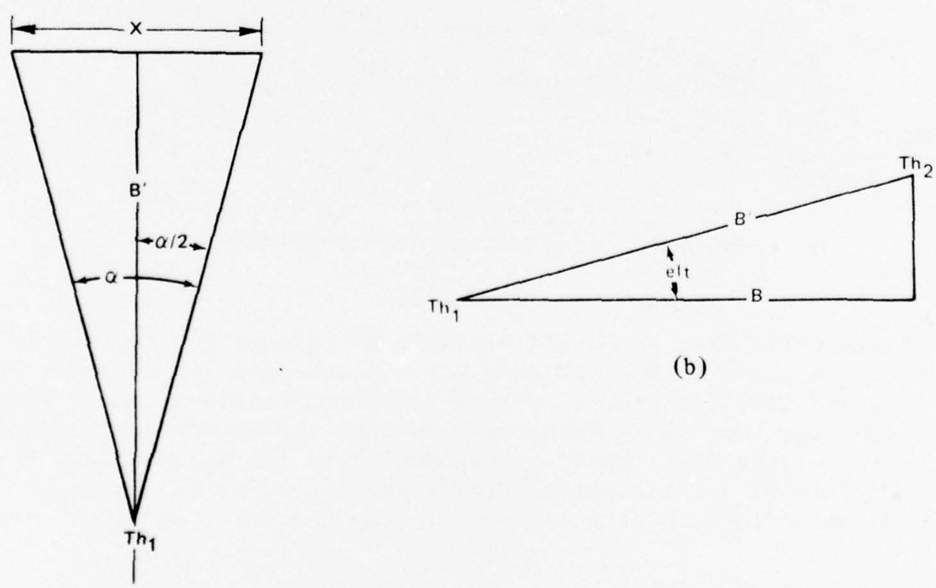
With B now determined, the angles θ_1 and θ_2 were measured. Then, by the Law of Sines,

$$R = \frac{B \sin \theta_2}{\sin (\theta_1 + \theta_2)},$$

where

R = the range from Th_1.

The theodolites used in this study were a Kern, model DMK-3, designated as the primary theodolite (Th_1), and a Wild, Model T-2, designated the secondary (Th_2). The subtense bar was also a Wild instrument.



(a)

(b)

FIGURE 4.

DATA-GATHERING PROCEDURE

Tentative sites from which to make LOS measurements were located on topographic maps. Precise location of the site to be measured was done at the scene. Table 1 gives the names by which the various sites were designated for the study and their locations, along with the number of radials along which measurements were made for each. Th_1 was set up on the spot designated as the site. The tripod for Th_2 was located at least 40 m (100 ft) away in a spot with unobscured visibility of Th_1 and, if possible, somewhat uphill from Th_1 so that anything visible to Th_1 would probably be visible to Th_2.

Th_1 was leveled by its operator while the subtense bar was mounted on the Th_2 tripod. The angular subtense of the bar was measured by Th_1 and recorded. Th_2 then was mounted and leveled. The vertical leveling bubble in each theodolite was centered, and the elevation angle, elt, between the two theodolites was measured, each using the crosshairs intersection of the other scope as target. If the measurements of elt were not within 20 seconds of each other, measurements were repeated until they were. While the theodolites were aimed at each other, the azimuth scale on Th_1 was set to 0 deg and that on Th_2 to 180 deg. This completed the setup procedure.

To begin making measurements, Th_1 was rotated to the first azimuth value (radial) indicated on the data-recording sheet. The crosshairs were set on the skyline, the vertical level adjusted, and the elevation read. The Th_2 operator looked through the scope of Th_1 at the position on the horizon on which the crosshairs were set, went back to Th_2, and placed its crosshairs on the same spot on the horizon. This process sometimes required a few iterations. When it was agreed that both theodolites were looking at precisely the same spot, the azimuth was read on Th_2. The nature of the mask object was recorded, i.e., a hill, rock outcrop, or tree.

For the next measurement, the scope of Th_1 was lowered to the next mask object down from the skyline and the process repeated. This was done for up to four mask objects along the radial, the closest ones to the site being ignored if there were more than four. The radials were done in four groups of four opposing radials at each site, as shown in Figure 5. This was for two reasons: first, if all 16 radials could not be completed (due to weather or time limitations), the sampling would not be lopsided; and, second, in case an undetected, systematic error developed, it would be spread over all the data, rather than deforming one segment.

TABLE 1. List of Tentative Sites for LOS Measurements.

Terrain type	Name of site	No. of radials	Geographic location
A. Fairly flat farmland; thick forests in distance	High Falls	16	Near Ft. Rucker, AL
	High Bluff 1	16	
	Allen	16	
	Toth 1	16	
	Toth 2	16	
B. Fairly smooth desert with little vegetation	Y-1	11	Near Ridgecrest, CA
	Y-2	13	
	Y-3	15	
	Y-4	16	
	Rademacher 3	16	
C. Rolling farmland; thick forests close	David Hendricks	16	Near Ft. Rucker, AL
	Dundee	16	
	Clayhatchee 1	16	
D. Moderately rough desert and rolling hills with little vegetation	Wilson Canyon 1	12	NWC range, China Lake, CA
	Wilson Canyon 2	10	
	Mt. Springs Canyon 2		
	Rademacher 1	19	Near Ridgecrest, CA
		15	
	Cameron 1	13	Near Monolith, CA
	Cameron 2	16	
E. Fairly flat farmland with thick forests close	Slocomb	16	Near Ft. Rucker, AL
	High Bluff 2	16	
	Clayhatchee 2	16	
	Clayhatchee 3	16	
	Clayhatchee 4	16	
F. Gently rolling hills with scattered trees	Golden Hills 1	16	Near Tehachapi, CA
	Golden Hills 2	16	
	Stallion Springs 3	16	
	Stallion Springs 4	16	
G. Rough desert with little vegetation	Wilson Canyon 3	16	NWC range, China Lake, CA
	Mt. Springs Canyon 1	19	
	Mt. Springs Canyon 3	15	
	Mt. Springs Canyon 4	16	
	Rademacher 2	19	Near Ridgecrest, CA
H. Sharply rolling hills with thickly scattered trees	Stallion Springs 1	16	Near Tehachapi, CA
	Stallion Springs 2	14	

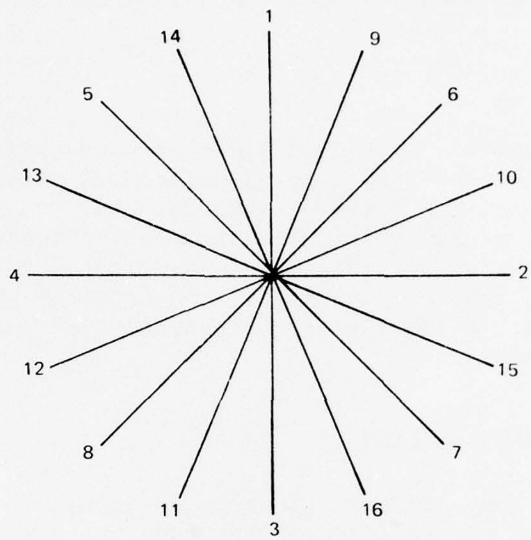


FIGURE 5. *Order in Which Radials Were Measured.*

Several problems were encountered using this method. One was the difficulty of locating, on the scope of Th_2, a precise, tiny spot seen as the crosshairs intersection point in the scope of Th_1. Operator training in the process partially overcame this problem. Leveling the theodolites was time-consuming; the instruments were re-leveled and the 0- to 180-deg line reset if either of them was bumped or if suspicious readings were obtained. It sometimes happened that the point at which Th_1 was aimed was masked from Th_2 by a tree or hill. In these cases, Th_1 was rotated a degree or two until a mutually visible point was found. Of course, the azimuth reading on the data sheet of the primary theodolite was changed accordingly. A sample data-recording form and procedure list are shown in Appendix B.

At each site, 12 photographs were taken looking out from the site, starting on the north radial and moving counterclockwise in a circle. Aerial photographs were taken of the terrain where the sites were located. In most cases the individual sites are shown in the pictures.

DATA REDUCTION AND RESULTS

COMPUTER PROGRAMS

Two computer programs for the UNIVAC 1108 were written and used to reduce the data, which consisted of mask angles and azimuth angles, as well as angles for measuring B (see Figure 3). One program computes and plots probability curves and critical altitudes for individual sites. The other program combines probabilities and critical altitudes from individual sites into summary probability and critical altitude curves for each terrain tvpe. A listing of the programs and instructions for their use are in Appendix C.

LOS AS A FUNCTION OF TERRAIN

The body of the *Line-of-Sight Handbook* contains critical altitude curves and two sets of probability curves: one for altitudes below 1000 m and another for altitudes below 5000 m, for each terrain type. Aerial and ground photographs and topographic maps are included for each type of terrain measured. An example of all these items for one of the terrain types is shown in Figures 6a and b, 7a and b, 8, 9, and 10a and b. The handbook's appendix contains the same information for each individual site. An example of individual site data is shown in Figures 11a, b, and c, 12a, b, and c, 13, and 14.

Figure 15 shows the terrain types included in this studv, listed in order from that with the least masking to that with the most. The ranking is based on a comparison of the probability curves from the various tvpes. In an effort to find measures that might correlate with LOS probability, the average angle between the skyline and the horizontal plane and the median range to the skyline were computed for each site. Figure 15 shows the average of the average skyline angles of all the sites in each terrain type. The standard deviations about these means are also shown. The average skyline angles were rank-ordered and the Spearman rank correlation coefficient, r_s, was computed with the ollowing equation:

$$r_s = \frac{6 \sum d_i^2}{n\,(n^2 - 1)},$$

where

d_i = the difference between ranks for each terrain type,

n = the number of terrain types.

For this study, $r_S = 0.95$, which is significant at the 0.005 level. It is not surprising that average skyline angle and probability of LOS are closely correlated, since the computation of the probability depended in part on the skyline angle. However, it does indicate that the need to measure masking objects below the skyline should be reevaluated before more masking measurements are made. The effort may be worthwhile only for very low altitudes.

In Figure 16, the average median range to the skyline is shown for the eight terrain types. The standard deviations around these means were huge, so caution must be used when interpreting this plot. It is interesting to note the relatively long median ranges to skyline for desert and mountain foothill sites compared to farmland sites.

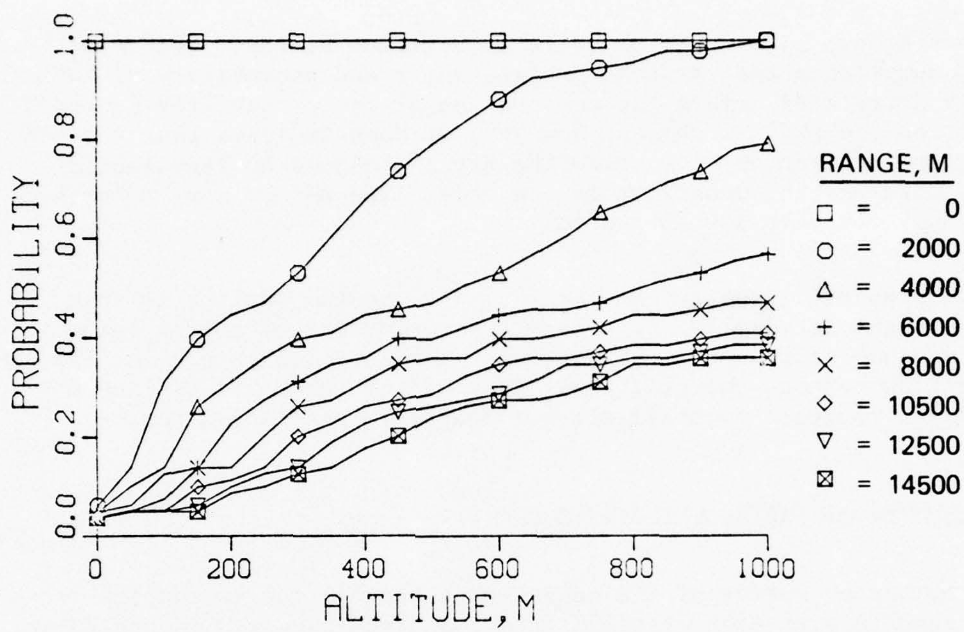
COMPARISON OF FIELD AND MAP DATA

A minor objective of the measurement program was to compare the field results with data obtained from topographic maps. Figure 17 (a, b, and c) plots probability curves computed by Erickson[3] on the same graphs with results from this study. The terrain categories were the same, but the actual terrain measured was different. The agreement between the map and measured curves is reasonably good, especially for the fairly smooth and the rough cases. This agreement is no doubt aided by the fact that vegetation was not a significant factor for the desert terrain types. Probability curves from map data have not been computed for other terrain types. These could readily be done if the need arises.

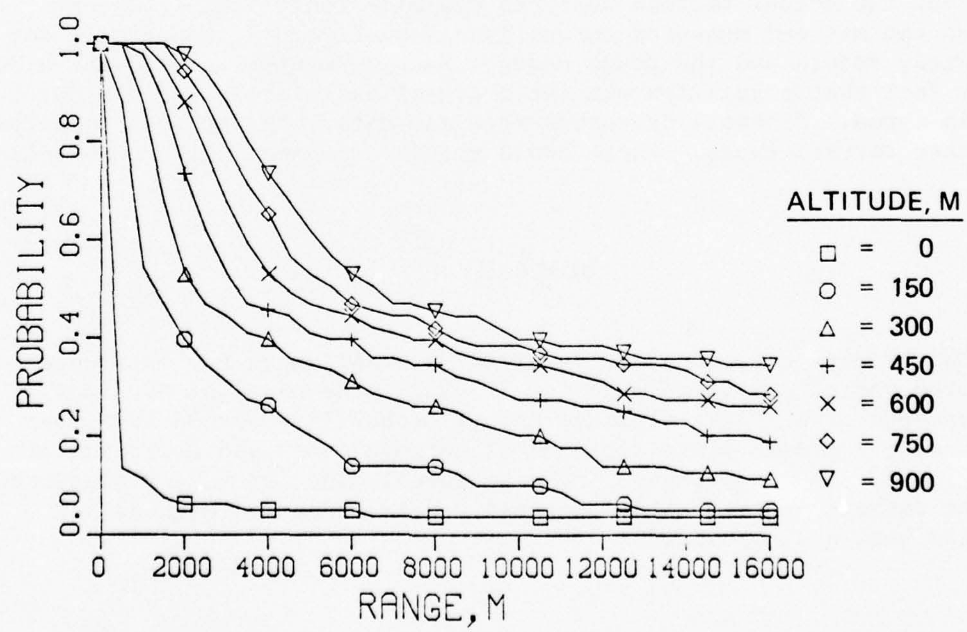
SUMMARY

This report has presented detailed information on how data were collected and calculations made for TP 5908, *Line-of-Sight Handbook*. The concepts of critical altitude and of probability of LOS have been explored, along with classification of terrain types and selection of sites for making measurements. The equipment used for making measurements and the techniques used were described. Data reduction methods and examples have been provided.

[3] Naval Ordnance Test Station. *Empirically Determined Effects of Gross Terrain Features Upon Ground Visibility From Low-Flying Aircraft*, by Ronald A. Erickson. China Lake, Calif., NOTS, 13 September 1961. (NAVWEPS Report 7779, NOTS TP 2760, publication UNCLASSIFIED.)



(a)



(b)

FIGURE 6. Average Probability of LOS in Rough Desert With Little or No Vegetation as a Function of (a) Altitude Up to 1000 m, and (b) Range.

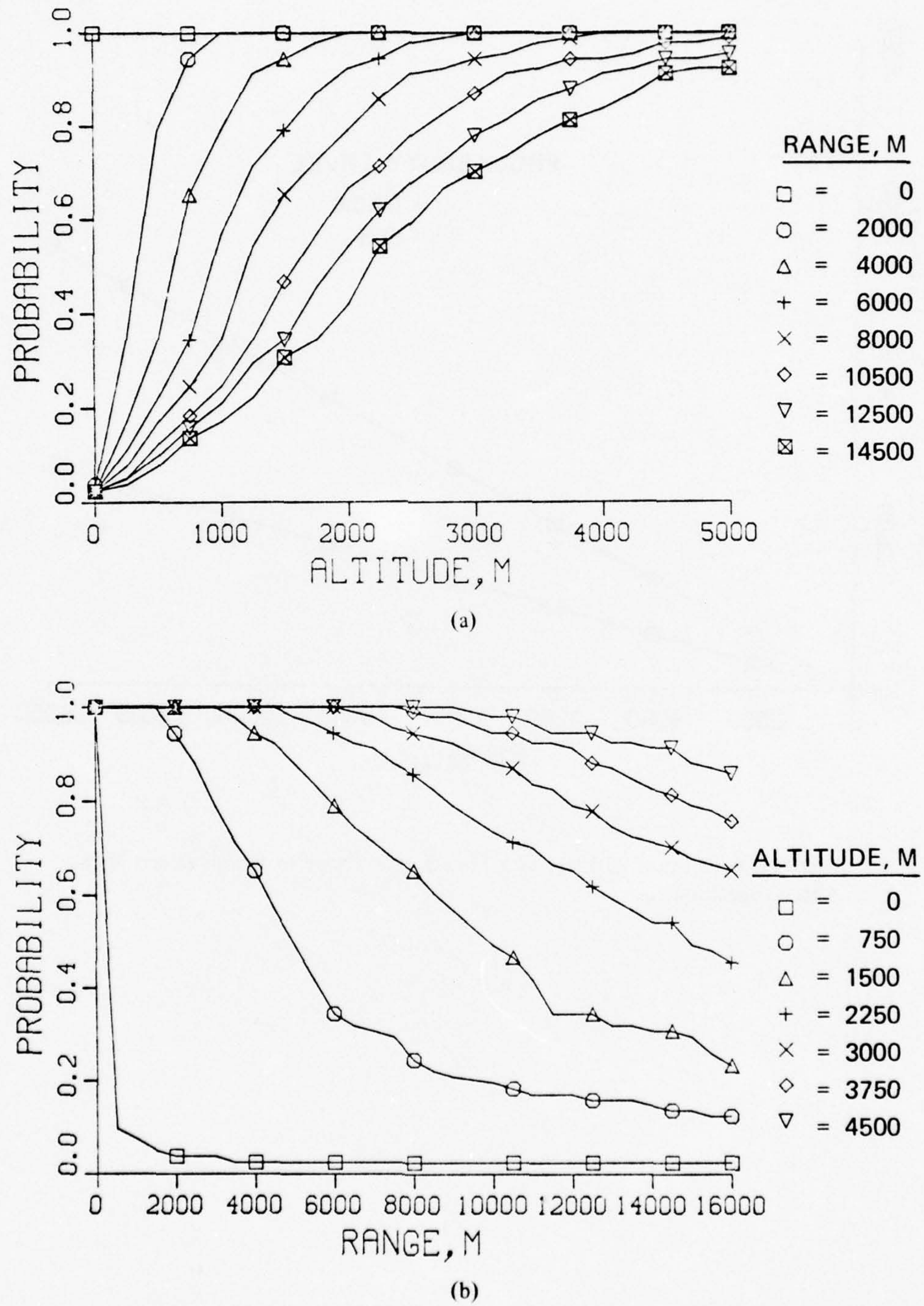


FIGURE 7. Average Probability of LOS in Rough Desert With Little or No Vegetation as a Function of (a) Altitude Up to 5000 m, and (b) Range.

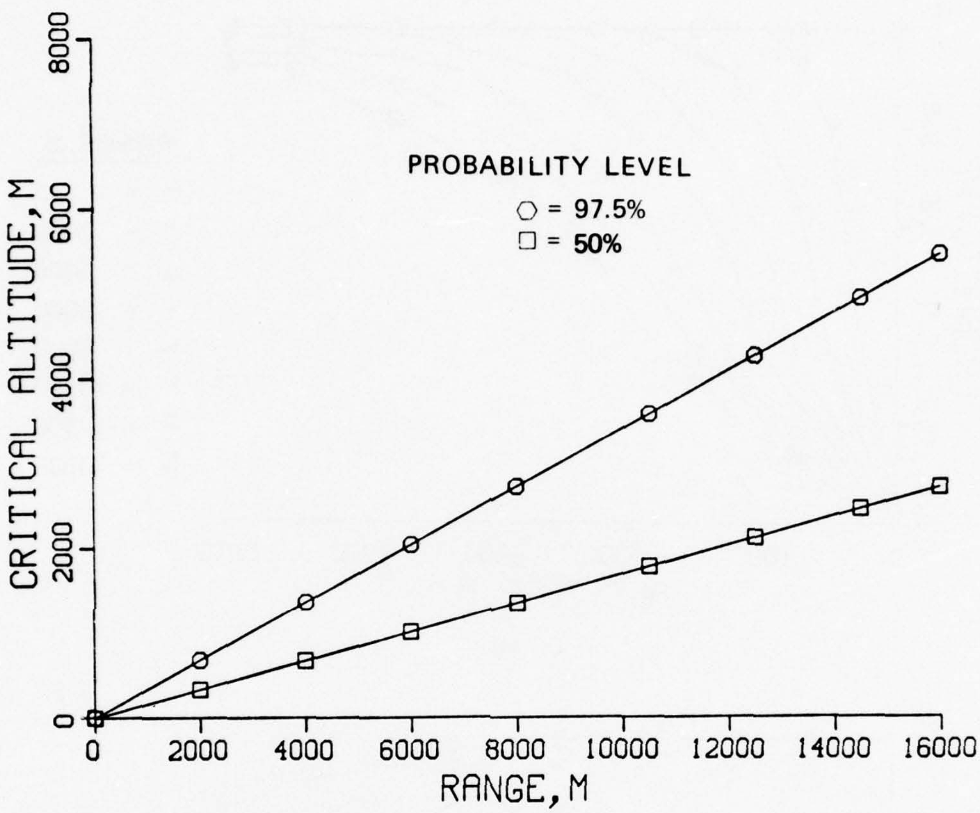


FIGURE 8. Critical Altitude as a Function of Range in Rough Desert With Little Vegetation.

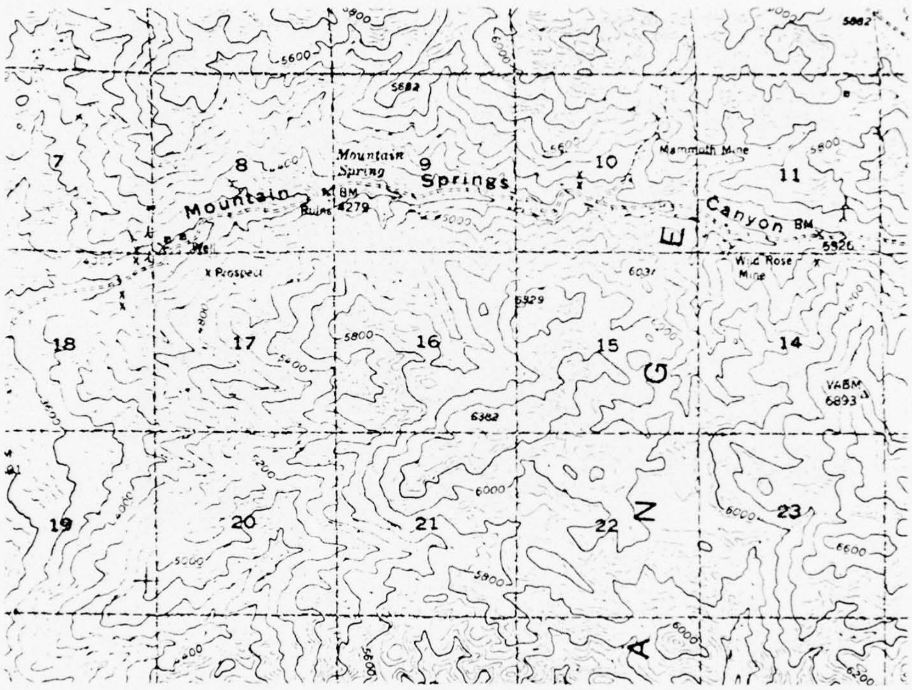


FIGURE 9. Topographic Map of Rough Desert.
Scale is 1:62,500; contour interval is 40 ft.

(a) Aerial View.

(b) Ground View

FIGURE 10. Photographs of Rough Desert With Little or No Vegetation.

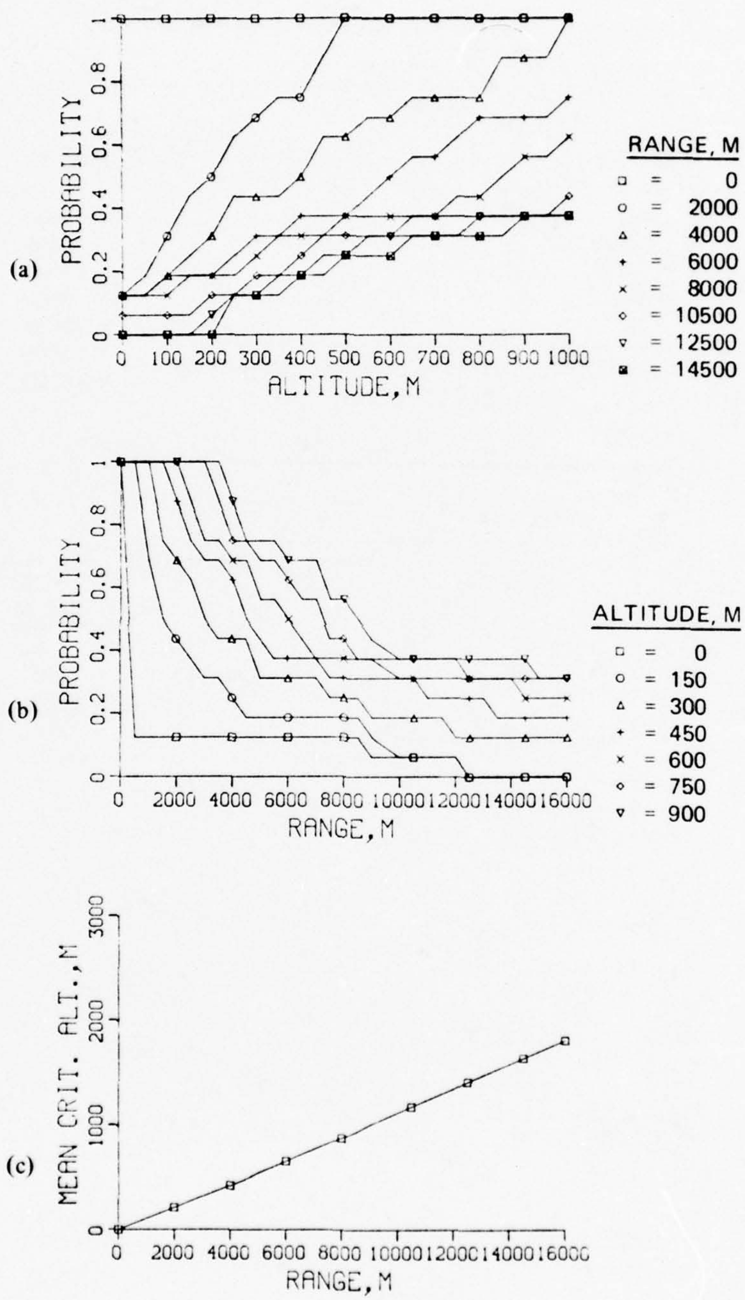


FIGURE 11. An Example of Data for an Individual Site, CM 2. Probability of LOS as a function of (a) altitude up to 1000 m, and (b) range; and (c) mean critical altitude as a function of range.

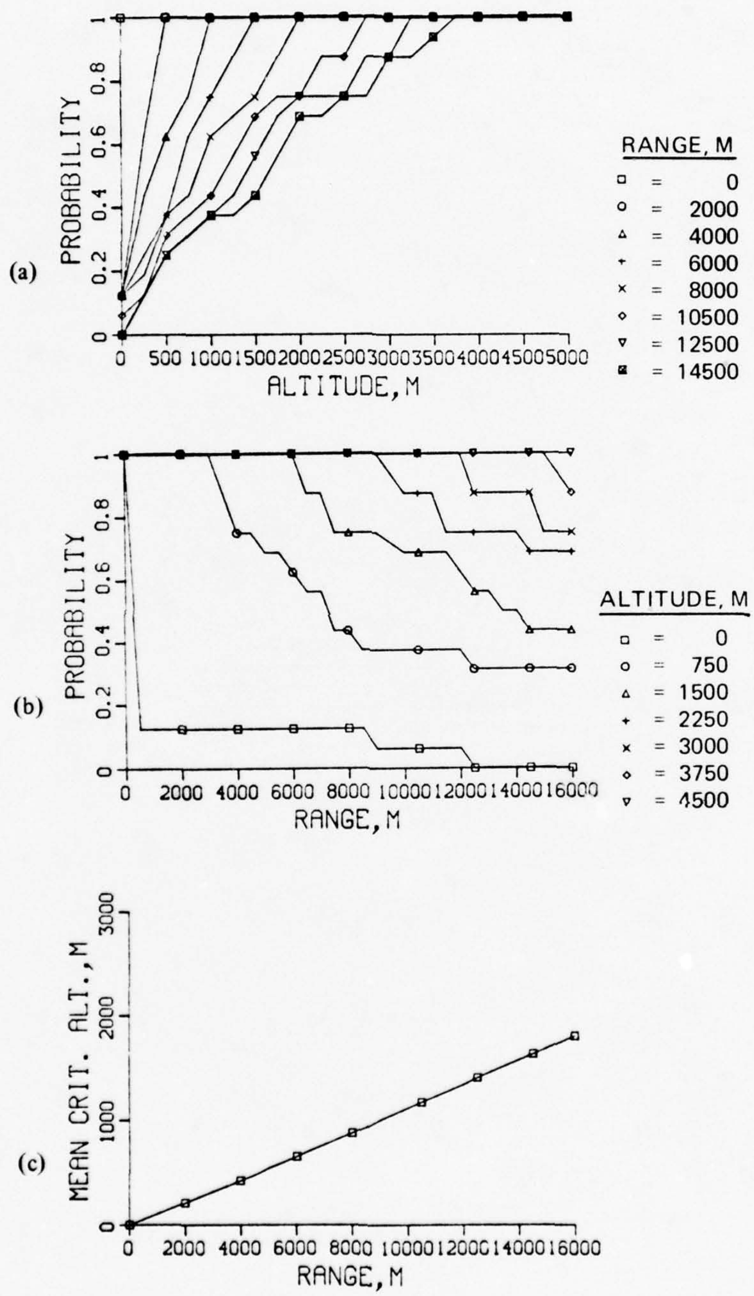


FIGURE 12. An Example of Data for an Individual Site, CM 2. Probability of LOS as a function of (a) altitude up to 5000 m, and (b) range; and (c) mean critical altitude as a function of range.

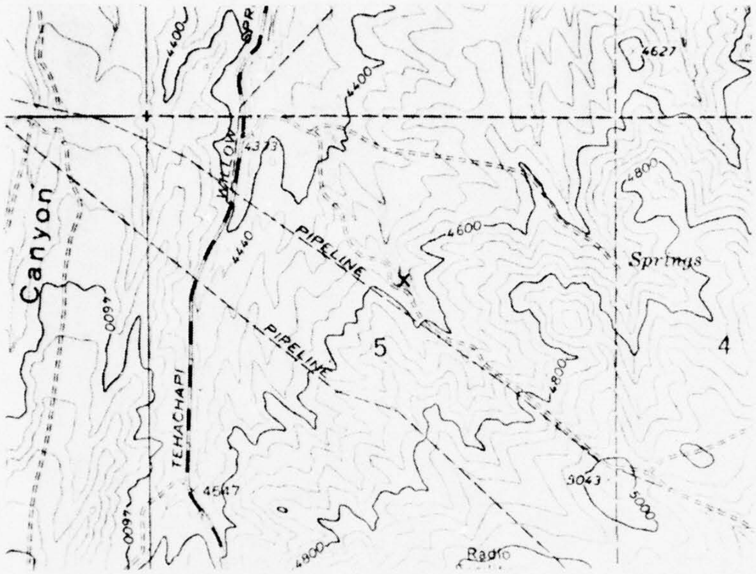


FIGURE 13. Site CM 2, Topographic Map. Scale is 1:24,000; contour interval is 40 ft.

(a) Aerial view, Sites CM 1 and CM 2.

(b) Ground view, Site CM 2.

FIGURE 14. Photographs of Sites CM 1 and CM 2.

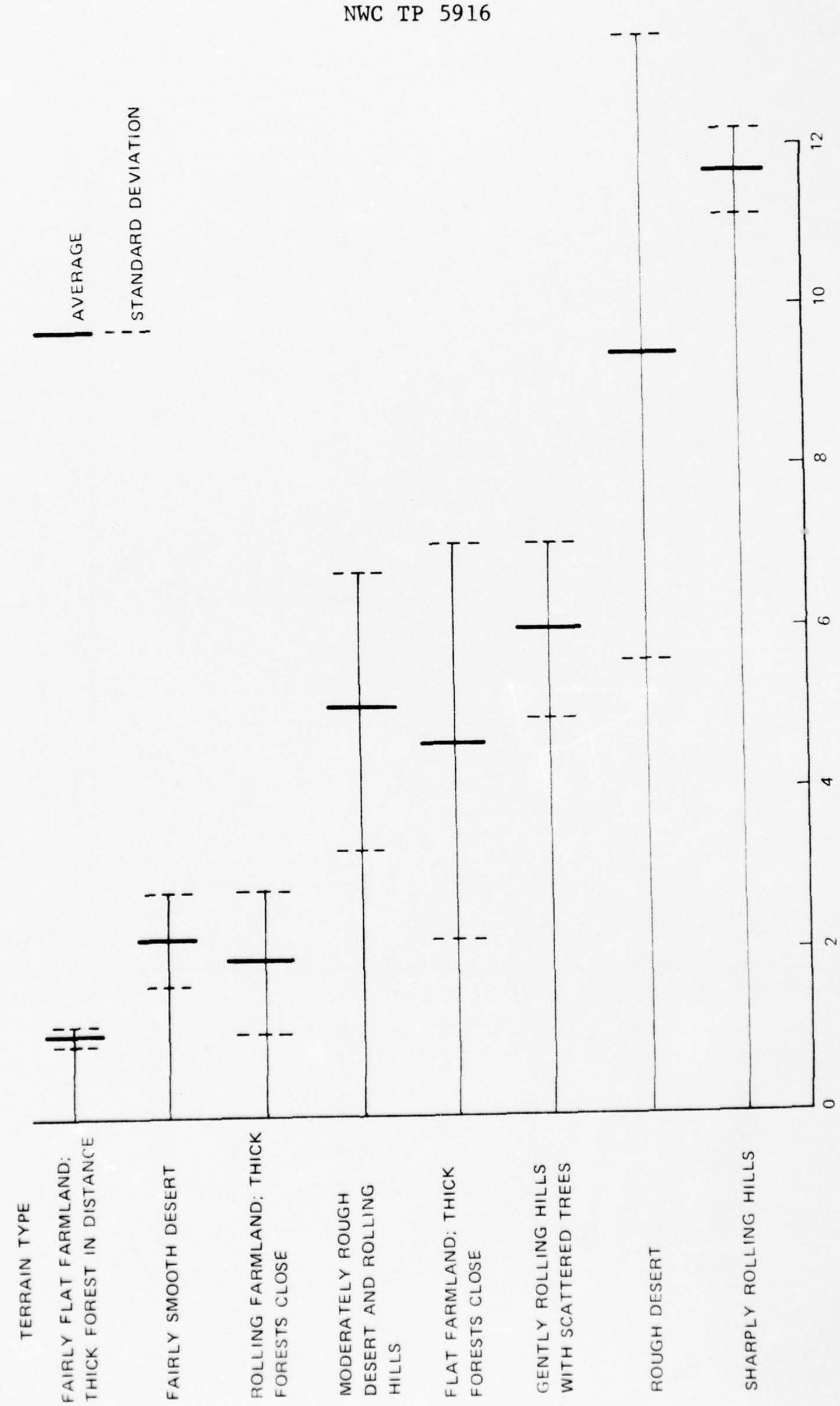


FIGURE 15. Average and Standard Deviation of Skyline Angle.

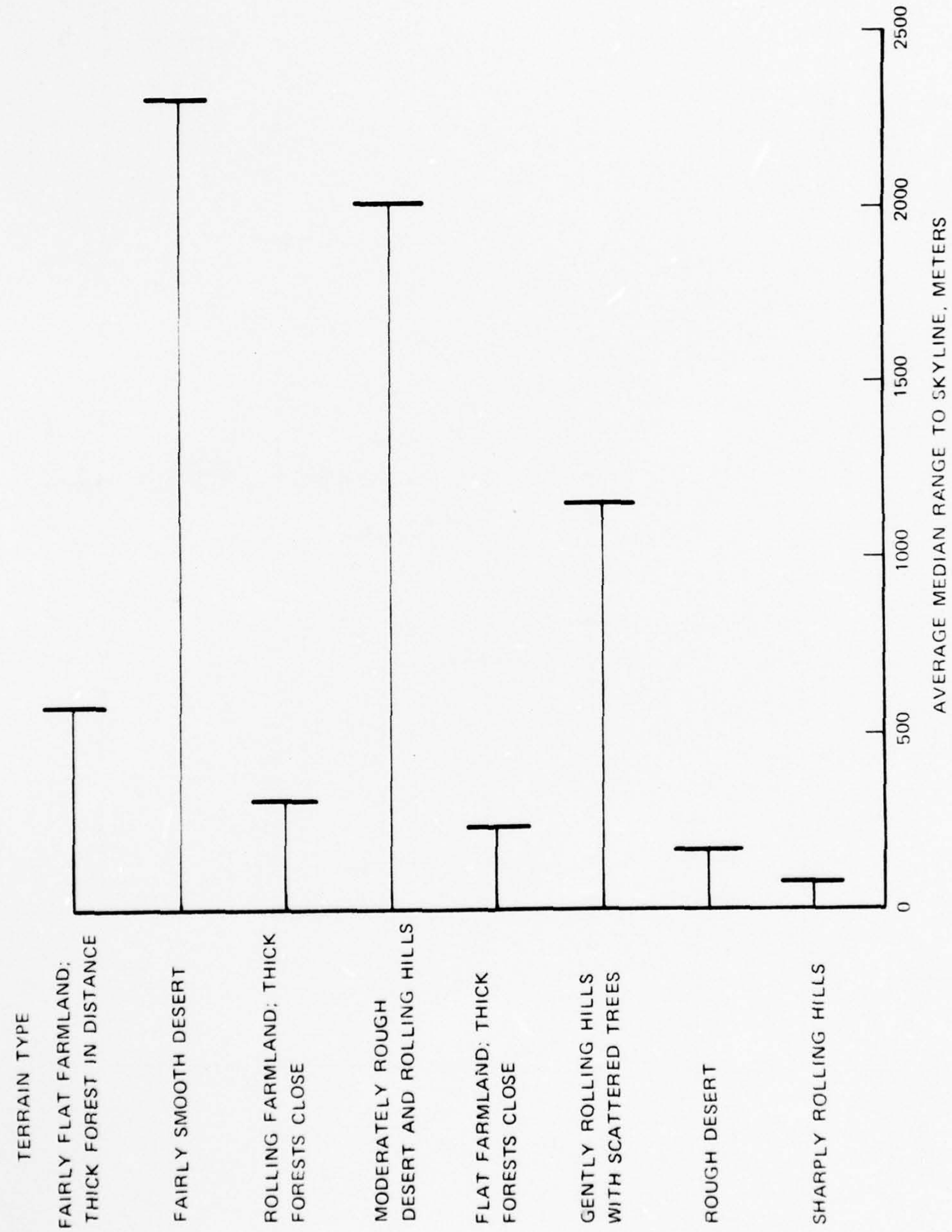
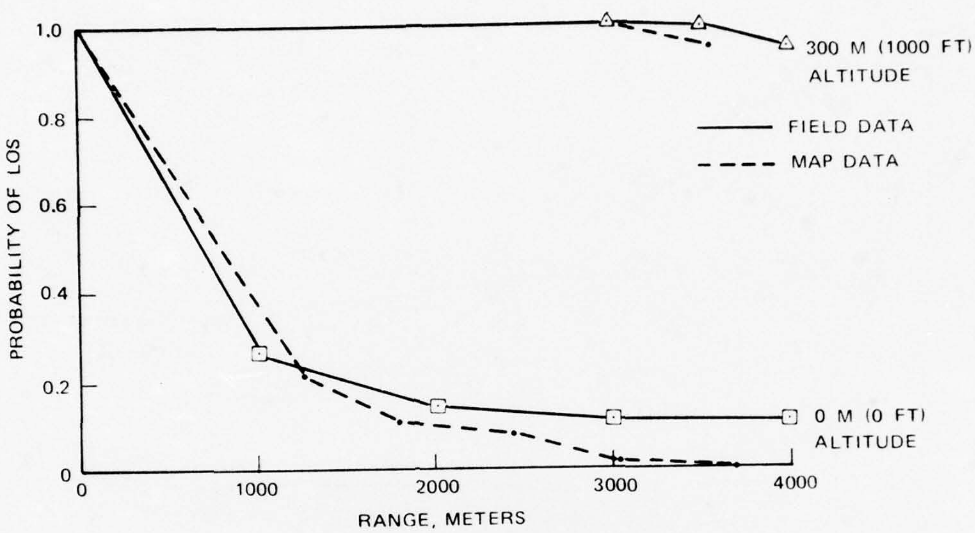
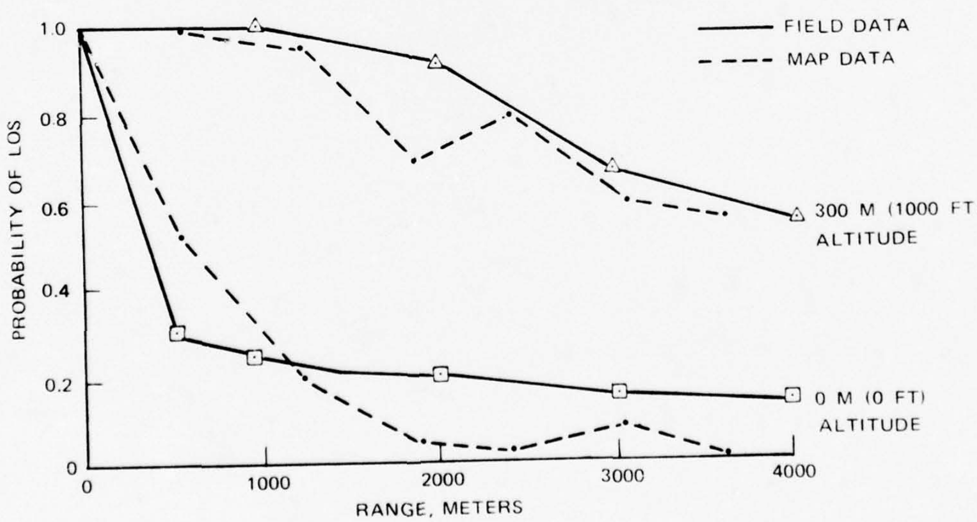


FIGURE 16. *Average Median Range to Skyline.*

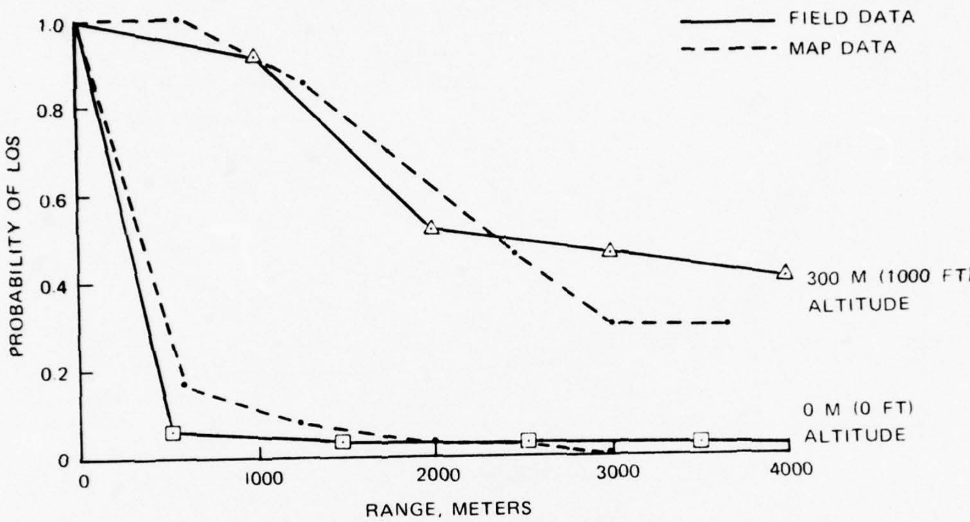


(a) Fairly smooth desert terrain.



(b) Moderately rough desert terrain and mountain foothills.

FIGURE 17. Comparison of Field and Map Data for Three Types of Desert Terrain.



(c) Rough desert terrain.

FIGURE 17. (Contd.)

Appendix A
CALCULATION OF REQUIRED NUMBER OF LOS MEASUREMENTS

The assumption was made that probability of LOS can be described by the binomial model, since for any particular sighting there are only two possibilities--either LOS exists or it does not.

Let p = probability that LOS exists;

then

$1-p$ = probability that it does not,

$\hat{p}$ = estimate of p made from the data,

α = probability that $\hat{p}$ lies within some tolerance, τ, of p,

$l = p - \tau$,

$u = p + \tau$.

Then $P[l < p < u] = \alpha$.

By the binomial expansion,

$$u,l \simeq \frac{n}{n + c^2}\left[\hat{p} + \frac{c^2}{2n} \pm c\sqrt{\frac{\hat{p}(1 - \hat{p})}{n} + \left(\frac{c^2}{2n}\right)}\right],$$

which can be simplified, by using the normal approximation to the binomial, to

$$u,l \approx \hat{p} \pm c\sqrt{\frac{\hat{p}(1 - \hat{p})}{n}}.$$

The normal approximation is good when p is close to 0.5.

$$\tau = c\sqrt{\frac{\hat{p}(1 - p)}{n}},$$

where c is a coefficient obtained from a table of the normal distribution. When solved for n, the above equation yields

$$n = \frac{c^2 p(1 - p)}{\tau^2}.$$

It was decided to strive for an estimate of p that would have a 0.95 probability of being within 0.1 of the true probability; therefore $\tau = 0.1$ and $\alpha = 0.95$. The following table was computed for a $\hat{p}$ of 0.5.

n	l	u
100	0.411	0.607
50	0.380	0.657
10	0.274	0.886

It appears that between 50 and 100 measurements are needed to fulfill the requirements when $\hat{p}$ is close to 0.5.

If $\hat{p} = 0.9$, the following table shows that between 36 and 50 measurements should be enough. Since the number of measurements required did not go up when $\hat{p}$ was raised to 0.9, it was decided that between 75 and 100 measurements for each terrain type should be enough.

n	l	u
50	0.815	0.992
36	0.799	1.01
10	0.692	1.14

Appendix B

PROCEDURE SHEET AND DATA RECORDING FORM

MASKING MEASUREMENT PROCEDURE

1. Set up primary tripod (Kern) at site. Rough level it. Mount Kern theodolite on it and level it.

2. Set secondary tripod about 67 strides (at least 100 ft) from the site. Mount the subtense bar on it and set it perpendicular to line from the other tripod.

3. Measure and record the horizontal angular subtense of the bar, alpha.

4. Mount and level the secondary theodolite on the secondary tripod.

5. Measure and record the elevation angle between theodolites using the center of scopes as targets, elt.

6. Set the 0- to 180-deg lines on the theodolites parallel to the line between tripods:

   a. From the primary, set the secondary at 180 deg (the primary reads 180 deg).

   b. From the secondary, set the primary at 0 deg.

7. On the primary theodolite, move the reticle along the skyline until the horizontal circle reading is 80 deg. Check the altitude level, then read and record elevation, El (top and bottom scale).

8. Place the reticle of the secondary theodolite at the same point on the skyline as the primary. Read and record the horizontal scale, Az_s (middle and bottom).

9. Lower the primary theodolite reticle to the next mask object down from the skyline, keeping the horizontal scale on 80 deg. Check and read vertical scale.

10. Place reticle of secondary theodolite on the same point and read horizontal scale.

11. Repeat steps 9 and 10 for as many as four mask objects along the radial. If there are more objects, ignore those closest to the site.

12. Repeat steps 7 through 11 for each azimuth shown on the data recording form.

Sheet 1 of 2

Date:__________ Site:__________ Alpha:__________ Elt:______

Th:__________ Terrain type:__________ No. Radials:________

Order	Az'	El	Az_s	Object	Comments
13	12				
5	35				
14	58				
1	80				
9	102				
6	125				
10	148				
2	170				
15	192				
7	225				
16	238				

Sheet 2 of 2

Site: ____________________

Order	Az'	El	Az'_s	Object	Comments
3	260				
11	282				
8	305				
12	328				
4	350				

Site description:

Camera Log:

Appendix C
COMPUTER PROGRAMS

Both programs were written in FORTRAN V for a UNIVAC 1110 computer.

PROGRAM PLOS

The program "PLOS" uses raw data to compute ranges to mask objects, then critical altitudes and probabilities of LOS.

Input Data

Card 1	NT ,	NR ,	NHF ,	NRP ,	NHP
Column	1-5,	6-10,	11-15,	16-20,	21-25

where

NT = the number of sites for which data are being submitted,

NR = the number of ranges at which probability is to be computed,

NHF = the number of altitudes at which probability is to be computed,

NRP: on the graphs of probability versus range, a symbol will be drawn every NRP range value,

NHP: on the graphs of probability versus altitude, a symbol will be drawn every NHP altitude value.

Card 2	R_1	R_2	. . . .	R_{12}
Column	1-6,	7-12,		67-72

Card 2a	R_{13}	. . . .	R_{NR}
Column	1-6,		

as many cards as needed.

R is the range at which probability of LOS is to be computed. Six columns are allowed for each range and the numbers must be right-justified.

Card 3	HF_1	HF_2	. . . . .	HF_{12}
Column	1-6,	7-12,		67-72

Card 3a $HF_{13} \cdots\cdots\cdots HF_{NH}$

.
.
.

as many cards as needed.

HF is the altitude at which probability of LOS is to be computed. Six columns are allowed for each altitude and the numbers must be right-justified.

For each site:

Card 1

	ALP,			ELT,				
Column	Deg	Min	Sec	Deg	Min	Sec	NM,	NTN
	1-3	4-6	7-10	13-15	16-19	20-21	25-27	31-36

where

ALP = angular subtense of the subtense bar in degrees, minutes, and seconds,

ELT = elevation angle between theodolites in degrees, minutes, and seconds,

NM = number of radials for this site,

NTN = a six-character alphanumeric identification of the site.

Card 2

	AZP,	DMSK,			AZS		
Column	Deg	Deg	Min	Sec	Deg	Min	Sec
	1-5	8-10	11-13	14-16	19-21	22-24	25-27

.
.
.

Card (4xNM): i.e., one card for each mask object measured, four cards/radial.

AZP = azimuth angle from primary theodolite in degrees,

DMSK = mask angle in degrees, minutes, and seconds,

AZS = azimuth angle from secondary theodolite in degrees, minutes, and seconds.

There must be four cards per radial. If that many mask objects were not measured, blank cards must be inserted.

Output

The program prints for each site:

1. The distance between theodolites, B.
2. AZP, mask angle, and range to mask object, for each mask object.
3. Average angle to the skyline and average range to the skyline mask object.
4. For each range:
   a. A critical altitude for every AZP.
   b. The mean critical altitude for the range.
5. A probability of LOS table with probability of LOS for every combination of altitude and range.

The program plots for each site (all on a single sheet):

1. Probability of LOS versus altitude--a curve for each range.
2. Probability of LOS versus range--a curve for each altitude.
3. Critical altitude versus range--a curve for mean critical altitude and a curve for the mean plus two standard deviations.

The program punches:

1. Mean critical altitude--one for each range, up to 12 per card.
2. Mean critical altitude plus two standard deviations--one for each range, up to 12 per card.
3. A probability table with a probability punched for each range--altitude combination.

PROGRAM AVPL

The program "AVPL" combines and summarizes the data from all the sites in a given type of terrain into a description of the terrain type.

Input Data

Card 1	NSETS
Column	1-5

NSETS = the number of types of terrain for which data is being submitted in this run.

For each terrain type:

Card 1	NT ,	NR ,	NHF ,	NRP ,	NHP ,	NTN
Column	1-5,	6-10,	11-15,	16-20,	21-25,	31-36

These variables are the same as those described for PLOS, Card 1, except for the addition of NTN. NTN is a six-character alphanumeric identifier of the terrain type.

Card 2	R_1	R_2	. . . .
Column	1-6	7-12	

Range cards--same as for PLOS.

Card 3 HF_1 HF_2. . . . .

Altitude cards--same as for PLOS.

For each site (punched by PLOS):

Card 1 Mean critical altitude . . .

NR of them, up to 12 per card.

Card 2 Mean critical altitude plus two standard deviations

NR of them, up to 12 per card.

Card 3 $P_{LOS\ 11}$ $P_{LOS\ 12}$ . . . . . $P_{LOS\ 1\ NHF}$

$P_{LOS\ 21}$ . . . . $P_{LOS\ NR,NHF}$

P_{LOS} = probability of LOS.

Output

AVPL prints the average probability table for each terrain type. AVPL plots:

1. The average probability versus altitude with one curve for each range.
2. The average probability versus range with one curve for each altitude.
3. Critical altitude versus range--one curve of the mean critical altitude and another for the mean plus two standard deviations.

Listing of the Computer Program PLOS

```
C  COMPUTES PLOS AS FUNCTION OF RANGE AND ALTITUDE.  INPUT DATA ARE MASK
C  ANGLES AROUND A TARGET.
C  NM=NUMBER OF MASK ANGLES PER TARGET
C  NR=NUMBER OF RANGES, NF=NUMBER OF FLIGHT ALTITUDES, NT=NUMBER OF TARGETS
C  NP=NUMBER OF PROBABILITIES =NRXNHF
        DIMENSION EMSK(20,4),RD(20,4),R(32),HC(32,20),HF(22),PROB(32,22)
       DIMENSION P(32),THETA(20),LABELP(6)
       DIMENSION ALP(3),ELT(3),AZP(72,4),DMSK(4,3),AZS(4,3),AZSC(72,4)
       DIMENSION AVEC(32),VAR(32),CA2SD(32)
       DIMENSION IPAK1(210),IPAK2(210)
       DIMENSION RLAB(2),HLAB(2)
   100 FORMAT (5I5)
   102 FORMAT (12F6.0)
   200 FORMAT (1H0'PLOS PROGRAM  SITE ',A6)
   201 FORMAT (1H07HRANGE =F7.0,6HMETERS)
   202 FORMAT (1H018HCRITICAL ALTITUDES)
   203 FORMAT (1H012F10.0)
   204 FORMAT (1H023HMEAN CRITICAL ALTITUDE=F7.0,6HMETERS)
   205 FORMAT (1H1'PROBABILITY OF LOS TABLE SITE ',A6)
   206 FORMAT (1H09HALTITUDE=10F10.0)
   207 FORMAT(1H05HRANGE)
   208 FORMAT(1H0F6.0,4X10F10.3)
   300 FORMAT(F1.0)
   315 FORMAT ('PROBABILITY OF LOS, SITE ',A6,'$')
   320 FORMAT('R=',F6.0,'$')
   325 FORMAT('ALT=',F6.0,'$')
       THETA(1)=0
       SBAR=0.
       DO3K=2,73
       K1=K-1
     3 THETA(K)=THETA(K1)+10.0*.00982
       CALL FR80ID(' 3175 C. BURGE PH. 3167')
       READ(5,100)NT,NR,NHF,NRP,NHP
       READ(5,102)(R(K),K=1,NR)
       READ(5,102)(HF(K),K=1,NHF)
       NM1=NM+1
       DO9K=1,NR
```

```
          AVEC(K)=0
        9 VAR(K)=0
          KS=0
          DO4K=1,NR,NRP
          KS=KS+1
          ENCODE(10,320,RLAB)R(K)
          CALL HEIGHT(0.08)
        4 CALL LINES(RLAB,IPAK1,KS)
          KS=0
          DO5K=1,NHF,NHP
          KS=KS+1
          ENCODE(11,325,HLAB)HF(K)
        5 CALL LINES(HLAB,IPAK2,KS)
          DO95LT=1,NT
          READ(5,104)(ALP(I),I=1,3),(ELT(I),I=1,3),NM,NTN
      104 FORMAT(3F3.0,3X,3F3.0,3X,I3,3X,A6)
          ALPH=(ALP(1)+ALP(2)/60+ALP(3)/3600)*.01745329/2
          ELTH=(ELT(1)+ELT(2)/60+ELT(3)/3600)*.01745329
          B=SBAR/(2*(SIN(ALPH)/COS(ALPH))*COS(ELTH))
          WRITE(6,200)NTN
          WRITE(6,499)B
      499 FORMAT(1H0'B IS ',F7.2,'METERS')
          WRITE(6,498)
      498 FORMAT(1H0'AZIMUTH      MASK ANGLE        RANGE')
          WRITE(6,497)
      497 FORMAT(1H ' (DEG)            (DEG)          (METERS) ')
          AVEM=0
          NMR=NM
          AVER=0
          DO10K=1,NM
          DO8I=4,1
          READ(5,103)AZP(K,I),(DMSK(I,J),J=1,3),(AZS(I,J),J=1,3)
      103 FORMAT(2X,F3.0,2X,3F3.0,2X,3F3.0,10X)
          AZS(I,3)=2*AZS(I,3)
          TST=2*AZS(I,3)
          IF(TST.LT.60)GO TO 6
          AZS(I,2)=AZS(I,2)+1.
          AZS(I,3)=AZS(I,3)-60.
        6 EMSK(K,I)=((DMSK(I,1)-90)+DMSK(I,2)/60+DMSK(I,3)/3600)
          IF(EMSK(K,I).LT.0)EMSK(K,I)=0
          AZSC(K,I)=(AZS(I,1)+AZS(I,2)/60+AZS(I,3)/3600)*.01745329
          AZP(K,I)=AZP(K,I)*.01745329
          ANG1=AZSC(K,I)
          ANG2=AZP(K,I)-AZSC(K,I)
          RD(K,I)=ABS(B*SIN(ANG1)/SIN(ANG2))
          AZP(K,I)=AZP(K,I)/.01745329
          WRITE(6,500)AZP(K,I),EMSK(K,I),RD(K,I)
      500 FORMAT(2X,F4.0,8X,F5.2,8X,F6.0)
          EMSK(K,I)=EMSK(K,I)*.01745329
        8 CONTINUE
          AVEM=AVEM+EMSK(K,4)
IAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
          IF(RD(K,4).EQ.0)NMR=NM-1
          AVER=AVER+RD(K,4)
```

```
          10 CONTINUE
             AVEM=AVEM/(NM*.01745329)
             AVER=AVER/NM
             WRITE(6,501)AVEM,AVER
         501 FORMAT(1H0'AVE SKYLINE ANGLE=',F5.2,'DEG, RANGE=',F6.1,'METERS')
             CALL OPNPLT
             DO 30K=1,NR
             AVE=0
             SSQ=0
             DO16I=1,NM
             TST=0
             DO15J=1,4
IAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
             IF(TST.EQ.1.)GO TO 15
IAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
             IF(EMSK(I,J).EQ.0)GO TO 15
             IF(R(K).LE.RD(I,J))GO TO 11
             IF(J.EQ.4)GO TO 13
             GO TO 15
          11 IF(J.GT.1)GO TO 12
             ANG=0
             GO TO 14
          12 JJ=J-1
             ANG=EMSK(I,JJ)
             GO TO 14
          13 ANG=EMSK(I,J)
          14 HC(K,I)=R(K)*TAN(ANG)
             TST=1.0
          15 CONTINUE
             AVE=AVE+HC(K,I)
          16 SSQ=SSQ+HC(K,I)**2.
             AVEC(K)=AVE/NM
             VAR(K)=(SSQ-(AVE**2.)/NM)/(NM-1)
             CA2SD(K)=AVEC(K)+2*(VAR(K))**0.5
             DO20I=1,NHF
             PROB(K,I)=0
             DO18L=1,NM
          18 IF(HF(I).GE.HC(K,L))PROB(K,I)=PROB(K,I)+1
          20 PROB(K,I)=PROB(K,I)/NM
             WRITE(6,200)NTN
             WRITE (6,201)R(K)
             WRITE (6,202)
             L2=0
             LIN=INT(NM/12)
             DO25L=1,LIN
             L1=L2+1
             L2=L*12
          25 WRITE(6,203)(HC(K,I),I=L1,L2)
             IF(L2.EQ.NM)GO TO 30
             L1=L2+1
             WRITE(6,203)(HC(K,I),I=L1,NM)
          30 WRITE(6,204)AVEC(K)
             NA=1
             CALL PHYSOR(3.0,7.0)
```

```
          CALL SCLPIC(0.5)
          ENCODE(35,315,LABELP)NTN
          CALL INTAXS
          CALL TITLE(' ',1,'ALTITUDE,MS',100,'PROBABILITYS',100,2.5,1.75)
          CALL MESSAG(LABELP,100,-0.25,2.75)
          CALL GRAF(0.,500.,5000.,0.,0.2,1.0)
          DO53K=1,NR,NRP
          DO52J=1,NHF
       52 P(J)=PROB(K,J)
       53 CALL CURVE(HF,P,NHF,2)
          NRL=INT(NR/NRP)
          CALL LEGEND(IPAK1,NRL,2.75,-.25)
          CALL ENDGR(0)
          WRITE (6,205)NTN
          NHF1=INT(NHF/10)
          L2=0
          IF(NHF.LT.10)GO TO 56
          DO55I=1,NHF1
          L1=L2+1
          L2=10*I
          WRITE(6,206)(HF(L),L=L1,L2)
          WRITE(6,207)
          DO55K=1,NR
      55  WRITE(6,208) R(K),(PROB(K,J),J=L1,L2)
       56 NHF2=NHF-10*NHF1
          IF(NHF2.EQ.0) GO TO 59
          L1=L2+1
          L2=L2+NHF2
          WRITE(6,206)(HF(L),L=L1,L2)
          WRITE (6,207)
          DO58K=1,NR
      58  WRITE(6,208)R(K),(PROB(K,J),J=L1,L2)
          PUNCH 600,(AVEC(K),K=1,NR)
          PUNCH 600,(CA2SD(K),K=1,NR)
      600 FORMAT(12F6.0)
          PUNCH 601,((PROB(K,J),J=1,NHF),K=1,NR)
      601 FORMAT(12F6.3)
       59 CALL PHYSOR(3.,4.0)
          CALL TITLE(' ',1,'RANGE,MS',100,'PROBABILITYS',100,2.5,1.75)
          CALL GRAF(0.,2000.,16000.,0.,0.2,1.0)
          CALL INTAXS
          DO65J=1,NHF,NHP
          DO60K=1,NR
       60 P(K)=PROB(K,J)
       65 CALL CURVE(R,P,NR,4)
          NHL=INT(NHF/NHP)
          CALL LEGEND(IPAK2,NHL,2.75,-0.25)
          CALL ENDGR(0)
          CALL PHYSOR(3.,1.5)
          CALL TITLE(' ',1,'RANGE,MS',100,'CRITICAL ALTITUDE,MS',100,2.5,1.7
         X5)
          CALL GRAF(0.,2000.,16000.,0.,2000.,6000.)
          CALL INTAXS
          CALL CURVE(R,AVEC,NR,NRP)
          CALL CURVE(R,CA2SD,NR,NRP)
          CALL ENDGR(0)
          CALL ENDPL(0)
       95 CONTINUE
          CALL DONEPL
          END

D OF COMPILATION:          3 DIAGNOSTICS.
```

Listing of the Computer Program AVPL

```
C PLOTS AVE PROB LOS FROM PROB TABLES
      DIMENSION AVEC(32),AVEW(32),CA2SD(32),CA2(32)
      DIMENSION R(32),HF(22),PROB(32,22),PROBA(32,22),P(32),LABELP(6)
      DIMENSION IPAK1(210),IPAK2(210),RLAB(2),HLAB(2)
      READ(5,100)NSETS
  100 FORMAT(I5)
      CALL FR80ID(' 3175 C.BURGE  PH. 3167')
      DO95LT=1,NSETS
      READ(5,101)NT,NR,NHF,NRP,NHP,NTN
  101 FORMAT(5I5,5X,A6)
      READ(5,102)(R(K),K=1,NR)
  102 FORMAT(12F6.0)
      READ(5,102)(HF(K),K=1,NHF)
C PACKS LEGENDS
      KS=0
      DO4K=1,NR,NRP
      KS=KS+1
      ENCODE(10,320,RLAB)R(K)
    4 CALL LINES(RLAB,IPAK1,KS)
  320 FORMAT('R=',F6.0,'$')
      KS=0
      DO5K=1,NHF,NHP
      KS=KS+1
      ENCODE(11,325,HLAB)HF(K)
    5 CALL LINES(HLAB,IPAK2,KS)
  325 FORMAT('ALT=',F6.0,'$')
      DO10K=1,NR
      AVEC(K)=0
      CA2(K)=0
      DO10I=1,NHF
   10 PROB(K,I)=0
      DO15L=1,NT
      READ(5,104)(AVEW(K),K=1,NR)
      READ(5,104)(CA2SD(K),K=1,NR)
  104 FORMAT(12F6.0)
      READ(5,103)((PROBA(K,I),I=1,NHF),K=1,NR)
  103 FORMAT (12F6.3)
      DO15K=1,NR
      AVEC(K)=AVEC(K)+AVEW(K)
      CA2(K)=CA2(K)+CA2SD(K)
      DO15I=1,NHF
   15 PROB(K,I)=PROB(K,I)+PROBA(K,I)
      DO20K=1,NR
      AVEC(K)=AVEC(K)/NT
      CA2(K)=CA2(K)/NT
      DO20I=1,NHF
   20 PROB(K,I)=PROB(K,I)/NT
      WRITE(6,200)NTN
  200 FORMAT(1H1'AVE PROB TABLE ',A6,' TERRAIN')
C WRITE AVE PROB TABLE
      NHF1=INT(NHF/10)
      LZ=0
      IF(NHF.LT.10)GO TO 36
      DO35I=1,NHF1
```

```
          L1=L2+1
          L2=10*I
          WRITE(6,206)(HF(L),L=L1,L2)
      206 FORMAT(1H09HALTITUDE=10F10.0)
          WRITE(6,207)
      207 FORMAT(1H05HRANGE)
          DO35K=1,NR
       35 WRITE(6,208)R(K),(PROB(K,J),J=L1,L2)
      208 FORMAT(1H0F6.0,4X10F10.3)
       36 NHF2=NHF-10*NHF1
          IF(NHF2.EQ.0)GO TO 39
          L1=L2+1
          L2=L2+NHF2
          WRITE(6,206)(HF(L),L=L1,L2)
          WRITE(6,207)
          DO38K=1,NR
       38 WRITE(6,208)R(K),(PROB(K,J),J=L1,L2)
    C PLOT AVE PROB AS FN OF ALTITUDE
       39 CALL PHYSOR(2.,5.5)
          ENCODE(35,315,LABELP)NTN
      315 FORMAT('AVE PROB LOS ',A6,' TERRAIN','$')
          CALL RESET('INTAXS')
          CALL XINTAX
          CALL TITLE(' ',1,'ALTITUDE,M$',100,'PROBABILITY$',100,3.75,2.75)
          CALL MESSAG(LABELP,100,-0.25,3.5)
          CALL GRAF(0.,1000.,5000.,0.,0.2,1.0)
          DO45K=1,NR,NRP
          DO44J=1,NHF
       44 P(J)=PROB(K,J)
       45 CALL CURVE(HF,P,NHF,NHP)
          NRL=INT(NR/NRP)
          CALL LEGEND(IPAK1,NRL,4.0,0.25)
          CALL ENDGR(0)
    C PLOT AVE PROB AS FN OF RANGE
          CALL PHYSOR(2.,1.5)
          CALL TITLE(' ',1,'RANGE,M$',100,'PROBABILITY$',100,3.75,2.75)
          CALL GRAF(0.,2000.,16000.,0.,0.2,1.0)
          CALL XINTAX
          DO55J=1,NHF,NHP
          DO50K=1,NR
       50 P(K)=PROB(K,J)
       55 CALL CURVE(R,P,NR,NRP)
          NHL=INT(NHF/NHP)
          CALL LEGEND(IPAK2,NHL,4.0,0.25)
          CALL ENDGR(0)
          CALL ENDPL(0)
    C PLOT AVE CRITICAL ALT AS FN OF RANGE
          CALL PHYSOR(2.,5.5)
          CALL INTAXS
          CALL TITLE(' ',1,'RANGE,M$',100,'CRITICAL ALTITUDE,M$',100,3.75,2
         X75)
          CALL GRAF(0.,2000.,16000.,0.,2000.,6000.)
          CALL CURVE(R,AVEC,NR,NRP)
          CALL CURVE(R,CA2,NR,NRP)
          CALL ENDGR(0)
          CALL ENDPL(0)
       95 CONTINUE
          CALL DONEPL
          END

D OF COMPILATION:        NO  DIAGNOSTICS.
```

INITIAL DISTRIBUTION

12 Naval Air Systems Command
   AIR-04 (1)
   AIR-104 (1)
   AIR-30212 (2)
   AIR-340D (1)
   AIR-340F (1)
   AIR-4131 (1)
   AIR-510 (1)
   AIR-5313 (2)
   AIR-954 (2)
4 Chief of Naval Operations
   OP-098 (1)
   OP-0982 (1)
   OP-55 (1)
   OP-987P10 (1)
2 Chief of Naval Material (MAT-0344)
4 Naval Sea Systems Command
   SEA-03 (1)
   SEA-03416 (1)
   SEA-09G32 (2)
3 Chief of Naval Research, Arlington
   ONR-211 (1)
   ONR-455 (1)
   ONR-461 (1)
1 Bureau of Medicine & Surgery (Code 513)
1 Commandant of the Marine Corps
1 Air Test and Evaluation Squadron 4
1 Air Test and Evaluation Squadron 5
1 Naval Aerospace Medical Research Laboratory, Pensacola (Code L5)
7 Naval Air Development Center, Johnsville
   Code 402 (1)
   Code 4021 (1)
   Code 4022 (1)
   Code 4023 (1)
   Code 4024 (1)
   Code 403 (1)
   Technical Library (1)
1 Naval Air Force, Atlantic Fleet
1 Naval Air Force, Pacific Fleet
1 Naval Air Test Center (CT-176), Patuxent River (SY-72)
1 Naval Avionics Facility, Indianapolis
1 Naval Electronics Laboratory Center, San Diego
6 Naval Personnel Research and Development Center, San Diego
   Code 02 (1)
   Code 03 (1)
   Code 311 (2)
   Code 312 (2)

3 Naval Postgraduate School, Monterey
   Dr. James Arima (1)
   Dr. Gary Poock (1)
   Technical Library (1)
2 Naval Research Laboratory
1 Naval Submarine Medical Center, Naval Submarine Base, New London
1 Naval Surface Weapons Center, White Oak (Technical Library)
2 Naval Training Equipment Center, Orlando
   Code 215 (1)
   Technical Library (1)
1 Office of Naval Research Branch Office, Pasadena
1 Operational Test and Evaluation Force
3 Pacific Missile Test Center, Point Mugu
   Code 1226 (2)
   Technical Library (1)
1 Office Chief of Research and Development
1 Army Armament Command, Rock Island (AMSAR-SAA)
1 Army Combat Developments Command, Armour Agency, Fort Knox
1 Army Combat Developments Command, Aviation Agency, Fort Rucker
1 Army Combat Developments Command, Experimentation Command, Fort Ord (Technical Library)
1 Army Combat Developments Command, Field Artillery Agency, Fort Sill
1 Army Materiel Development & Readiness Command
1 Army Missile Command, Redstone Arsenal
1 Army Training & Doctrine Command, Fort Monroe
1 Aeromedical Research Laboratory, Fort Rucker
1 Army Ballistics Research Laboratories, Aberdeen Proving Ground
2 Army Human Engineering Laboratory, Aberdeen Proving Ground
2 Army Materiel Systems Analysis Agency, Aberdeen Proving Ground
1 Army Mobility Equipment Research & Development Center, Fort Belvoir (Library)
1 Army Research Institute, Arlington
1 Fort Huachuca Headquarters, Fort Huachuca
2 Frankford Arsenal
2 Picatinny Arsenal
   SMUPA-AD-C (1)
   SMUPA-FRL-P (1)
1 Redstone Arsenal (DRXHE-MI)
1 White Sands Missile Range
1 Air Force Logistics Command, Wright-Patterson Air Force Base
1 Air Force Systems Command, Andrews Air Force Base (SDW, Roger Hartmeyer)
1 Tactical Air Command, Langley Air Force Base
1 Oklahoma City Air Materiel Area, Tinker Air Force Base
3 Aeronautical Systems Division, Wright-Patterson Air Force Base
   Code AERR (1)
   Code RW (1)
   Code XR (1)
1 Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base (Code HEA)

1 Air Force Armament Laboratory, Eglin Air Force Base
(Technical Library)
12 Defense Documentation Center
2 Director of Defense Research & Engineering
TST&E (1)
DAD/E&LS (1)
1 Defense Intelligence Agency
1 Applied Physics Laboratory, JHU, Laurel, MD
2 Autonetics/Rockwell International Corp., Anaheim, CA
(Human Factors Group)
2 Calspan Corporation, Buffalo, NY (Life Sciences Avionics Dept.)
2 General Research Corporation, Santa Barbara, CA
3 Hughes Aircraft Company, Culver City, CA
(Display Systems Laboratory)
1 Human Factors Research, Inc., Goleta, CA
1 Institute for Defense Analyses, Arlington, VA (Technical Library)
2 McDonnell Douglas Corporation, Long Beach, CA (Director, Scientific
Research, R&D Aircraft Division)
2 McDonnell Douglas Corporation, St. Louis, MO (Engineering Pyschology)
1 Martin-Marietta Corporation, Orlando, FL
1 National Academy of Sciences, Vision Committee, Washington, D. C.
1 Rockwell International Corporation, Columbus, OH
2 Systems and Research Center, Minneapolis, MN (Vision & Training
Technology)
5 The Boeing Company, Seattle, WA (Crew Systems MS-41-44)
1 The Rand Corporation, Santa Monica, CA (Dr. H. H. Bailey)
1 University of California, Scripps Visibility Laboratory, San Diego, CA
2 Virginia Polytechnic Institute, Blacksburg, VA (Industrial Engineering
Department)
2 Vought, Incorporated, Systems Divison, Dallas, TX (Human Factors
Engineering)